Surface Modeling

Types:

Polygon surfaces

Curved surfaces

Volumes

Generating models:

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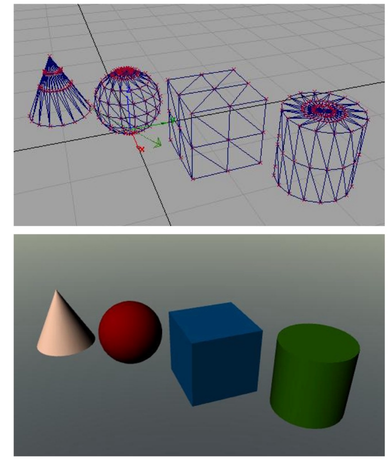
Polygon Surfaces

Set of surface polygons that enclose an object interior



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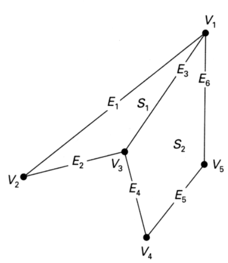
Polygon Tables

We specify a polygon surface with a set of vertex coordinates and associated attribute parameters



VERTEX TABLE
V_1: x_1, y_1, z_1
V_2: x_2, y_2, z_2
V_3: x_3, y_3, z_3
V_4: x_4, y_4, z_4
V_5: x_5, y_5, z_5

EDGE TABLE
E_1: V_1, V_2
E_2: V_2, V_3
E_3: V_3, V_1
E_4: V_3, V_4
E_5: V_4, V_5
E_6: V_5, V_1

POLYGON-SURFACE TABLE
S_1: E_1, E_2, E_3
S_2: E_3, E_4, E_5, E_6

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Curved Surfaces

- Implicit

  Curve defined in terms of an implicit function:

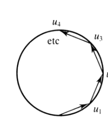
$$f(x, y, z) = 0$$

- Parametric

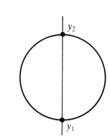
  Parametrically defined curve in three dimensions is given by three univariate functions:

$$Q(u) = (X(u), Y(u), Z(u))$$

$Q(u) = (\cos u, \sin u)$



parametric



implicit

$f(x, y) = x^2 + y^2 - 1 = 0$

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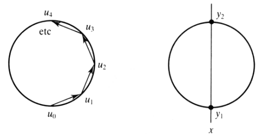
Implicit vs. Parametric

Surface Display

✓ Parametric



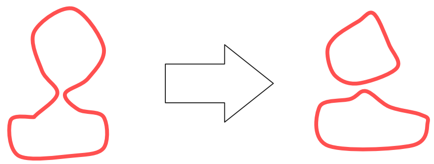
Surface Intersections

✓ Implicit

$$f_1(x,y,z) - f_2(x,y,z) = 0$$

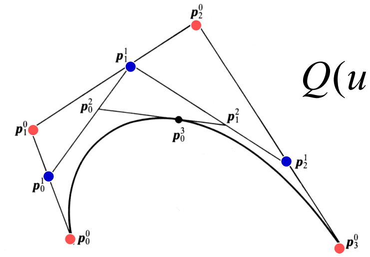
Changing Topology

✓ Implicit



Parametric Example: Beziér Curves

A Beziér curve can be defined in terms of a set of control points denoted in red. Consider, for example, a cubic, or curve of degree 3:



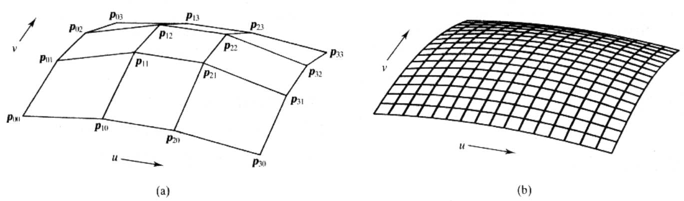
$$Q(u) = (1-u)^3 p_0 + 3u(1-u)^2 p_1 + 3u^2(1-u)p_2 + u^3 p_3$$

We can generate points on the curve by repeated linear interpolation.

Starting with the control polygon (in red), the edges are subdivided (as noted in blue). These points are then connected in order and the resulting edges subdivided. The recursion stops when only one edge remains. This allows us to approximate the curve at multiple resolutions.

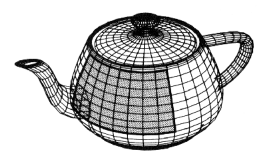
Beziér Patches

Control polyhedron with 16 points and the resulting bicubic patch:

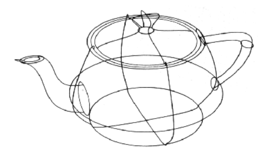


Example: The Utah Teapot

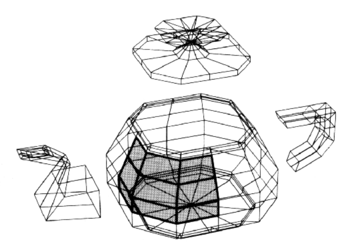
32 patches



single shaded patch

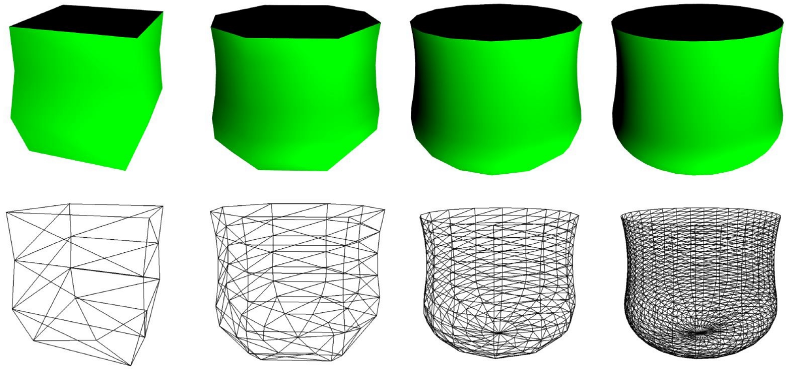


Patch edges



wireframe of the control points

Subdivision of Beziér Surfaces



2 8 32 128

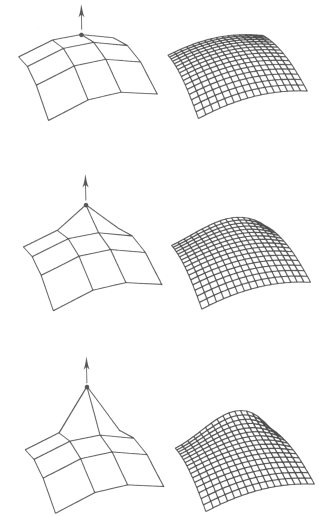
triangles per patch

We can now apply the same basic idea to a surface, to yield increasingly accurate polygonal representations

Deforming a Patch

✓The net of control points forms a polyhedron in cartesian space, and the positions of the points in this space control the shape of the surface.

✓The effect of lifting one of the control points is shown on the right.



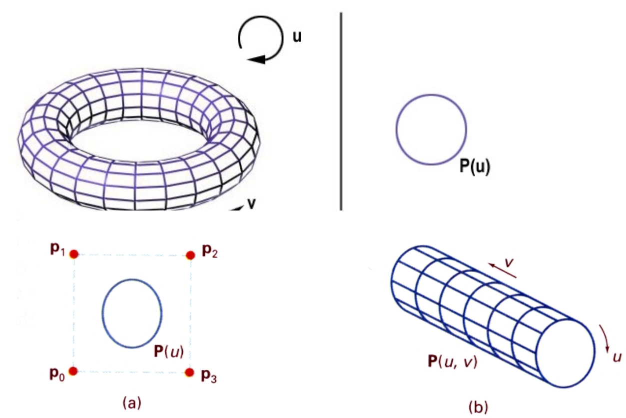
Patch Representation vs. Polygon Mesh

It's fair to say that a polygon is a simple and flexible building block. However, a parametric representation of an object has certain key advantages:

- Conciseness
  - A parametric representation is exact and economic since it is analytical. With a polygonal object, exactness can only be approximated at the expense of extra processing and database costs.
- Deformation and shape change
  - Deformations of parametric surfaces is no less well defined than its undeformed counterpart, so the deformations appear smooth. This is not generally the case with a polygonal object.

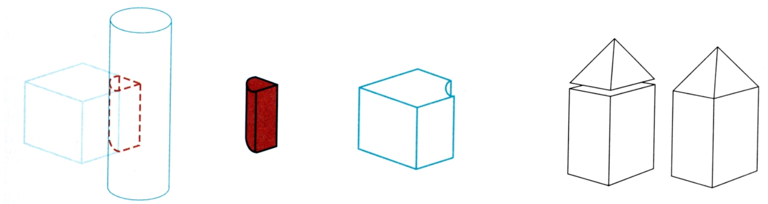
Sweep Representations

Solid modeling packages often provide a number of construction techniques. A good example is a sweep, which involves specifying a 2D shape and a "sweep" that moves the shape through a region of space.



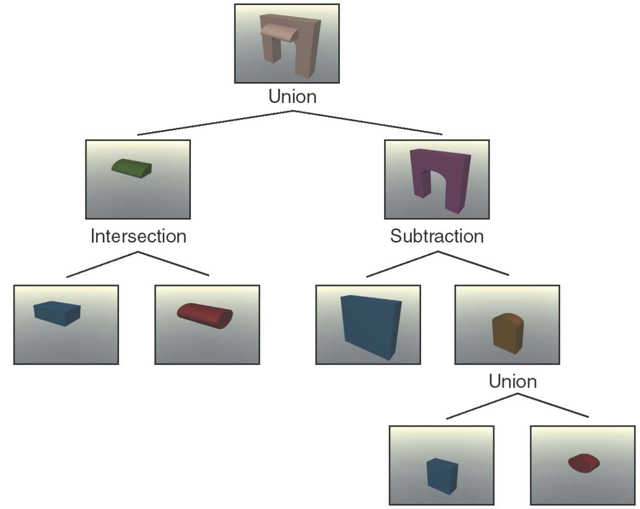
Constructive Solid-Geometry Methods (CSG)

Another modeling technique is to combine the volumes occupied by overlapping 3D shapes using set operations. This creates a new volume by applying the union, intersection, or difference operation to two volumes.

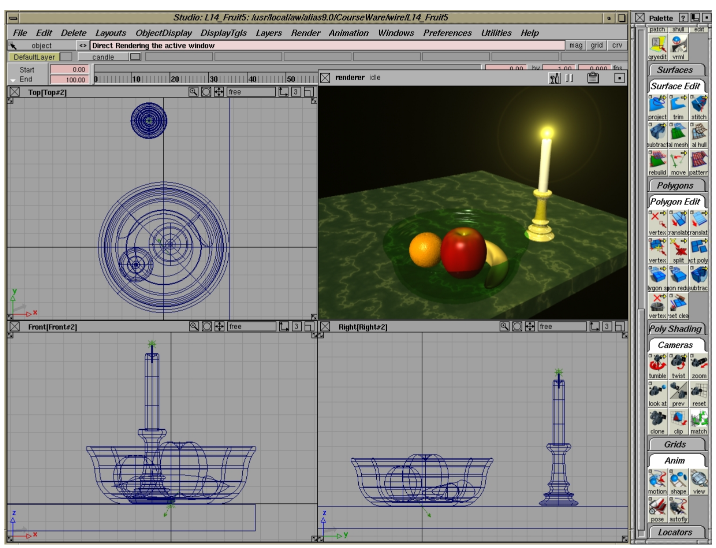


intersection difference union

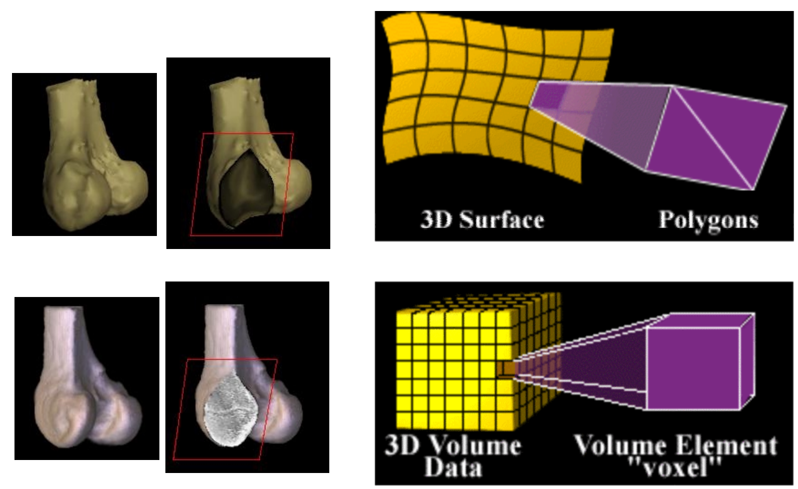
A CSG Tree Representation



Example Modeling Package: Alias Studio

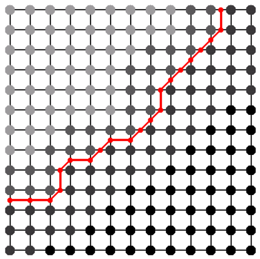


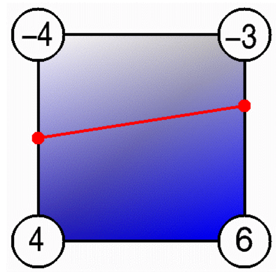
Volume Modeling



Marching Cubes Algorithm

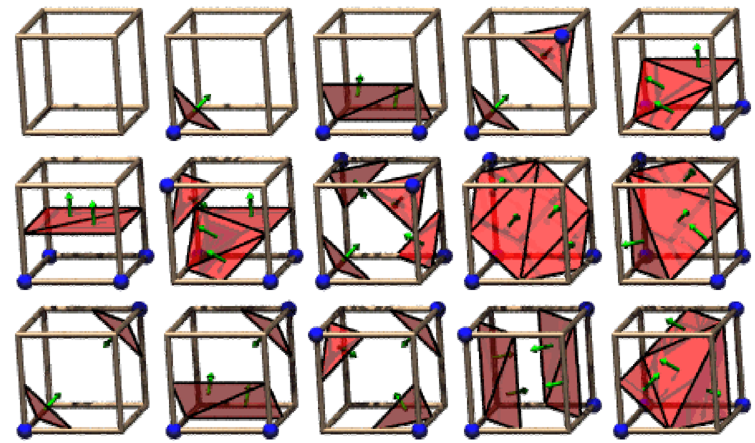
Extracting a surface from voxel data:





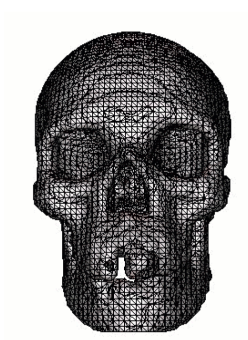
1. Select a cell
2. Calculate the inside/outside state of each vertex of the cell
3. Create an index
4. Use the index to look up the state of the cell in the case table (see next slide)
5. Calculate the contour location (via interpolation) for each edge in the case table

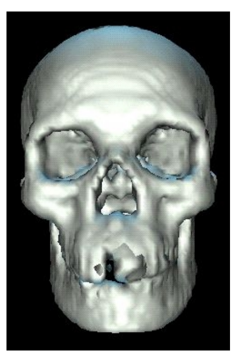
Marching Cube Cases



The 15 Cube Combinations

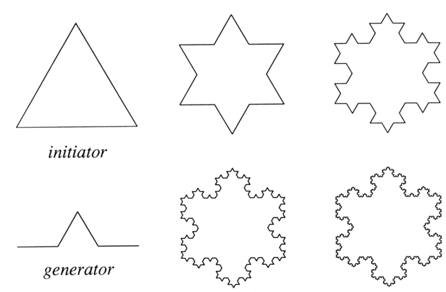
Extracted Polygonal Mesh





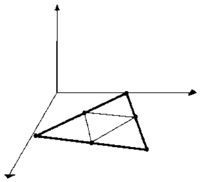
Procedural Techniques: Fractals

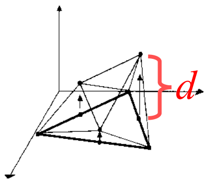
Apply algorithmic rules to generate shapes



Terrains

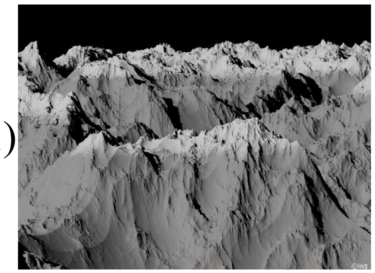
Midpoint Displacement





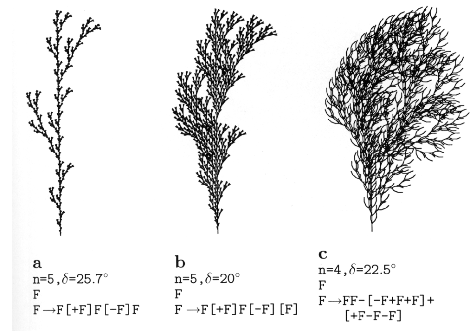
Example:

$$d = \text{edge size} \cdot \text{random}(-1,1)$$



Example: L-systems

Biologically-motivated approach to modeling botanical structures



Example of a complex L-system model

Next Time

Midterm